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Employee Performance Evaluation in a Spare Part Manufacturing Company from a Multicriteria Approach

Sercan EDİNSEL[1]

Keywords
Employees, Performance Appraisal, PF-AHP, PF-MARCOS, Human Resource Management.

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Abstract

Employees play a critical role in the success and sustainability of a business. Effective evaluation and improvement of employee performance is essential to achieve organizational success and sustain competitive advantage in a dynamic business environment. This study introduces a new approach to employee performance appraisal in a spare parts store in Turkey using a comprehensive framework that combines two important decision-making techniques: Pythagorean Fuzzy Analytic Hierarchy Process (PF-AHP) and Pythagorean Fuzzy Multi-Attribute Rating and Classification of Alternatives by Similarity to the Ideal Solution (PH-MARCOS). The hybrid use of these methods aims to address the inherent complexities and subjectivities in the evaluation of employee performance by considering multiple perspectives and objective criteria. The approach uses a structured and iterative method to determine the relative importance of performance dimensions and identify high-performing employees. The PF-AHP-MARCOS framework allows organizations to tailor the performance appraisal process to their specific cultural and business contexts and align it with their specific goals and objectives. The aim of this study is to evaluate the performance of employees in the warehouse department of a spare parts manufacturing company in Ankara using the eight-criteria PF-AHP-MARCOS method. As a result of the study, it was determined that the fourth employee showed the best performance and the first criterion "Job Quality" was determined as the most important criterion for warehouse employees.

Bir Yedek Parça Üretim Şirketinde Çok Kriterli Yaklaşımla Çalışan Performansı Değerlendirmesi

Anahtar Kelimeler
Çalışanlar, Performans Değerlendirme, PF-AHP, PF-MARCOS, İnsan Kaynakları Yönetimi.

Özet

Çalışanlar, bir işletmenin başarısında ve sürdürülebilirliğinde kritik bir rol oynar. Çalışan performansının etkin bir şekilde değerlendirilmesi ve iyileştirilmesi, dinamik bir iş ortamında örgütsel başarıya ulaşmak ve rekabet avantajını sürdürmek için gereklidir. Bu çalışma, iki önemli karar verme tekniğini birleştiren kapsamlı bir çerçeve kullanarak Türkiye'deki bir yedek parça mağazasında çalışanların performans değerlendirmesine yeni bir yaklaşım getirmektedir: Pisagor Bulanık Analitik Hiyerarşi Süreci (PF-AHP) ve Pisagor Bulanık Çok Öznitelikli Derecelendirme ve Alternatiflerin İdeal Çözüme Benzerliğine Göre Sınıflandırılması (PH-MARCOS). Bu

[1] ORCID: 0000-0003-2831-7504. Dr., OSTIM Technical University Guest Lecturer, FEAS, Business Administration, Turkey, sedinsel@gmail.com

yöntemlerin hibrit kullanımı, çoklu bakış açılarını ve objektif kriterleri dikkate alarak çalışanların performansının değerlendirilmesindeki içsel karmaşıklıkları ve öznellikleri ele almayı amaçlamaktadır. Yaklaşım, performans boyutlarının göreceli önemini belirlemek ve yüksek performanslı çalışanları tespit etmek için yapılandırılmış ve yinelemeli bir yöntem kullanmaktadır. PF-AHP-MARCOS çerçevesi, kuruluşların performans değerlendirme sürecini kendilerine özgü kültürel ve iş bağlamlarına göre uyarlamalarına ve belirli amaç ve hedefleriyle uyumlu hale getirmelerine olanak tanımaktadır. Bu çalışmanın amacı, Ankara'da yedek parça üretimi yapan bir şirketin depo bölümündeki çalışanların performanslarının sekiz kriterli PF-AHP-MARCOS yöntemi kullanılarak değerlendirilmesini amaçlamaktadır. Çalışmanın sonucunda dördüncü çalışanın en iyi performansı gösterdiğini ve birinci kriter olan "İş Kalitesi "nin depo çalışanları için en önemli kriter olarak belirlendiğini tespit edilmiştir.

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1. Introduction

In today's world, where environmental uncertainty is pervasive, the survival and sustainable competitive advantage of organizations of all sizes and in every sector depend on the uniqueness of human resources and the effective management of this valuable asset. Human resources, referring to individuals who directly or indirectly carry out organizational processes, including employees, can be described as the key to an organization's success or failure (Albrecht et al., 2015). This is where the role of the Human Resources department within the organization comes to the forefront. This department ensures that the strategic activities necessary for the organization's success are carried out from the highest level to the lowest unit, maximizing the performance of employees (Jackson, 1990).

Enhancing employee performance primarily hinges on the evaluation of their current performance. Performance appraisal is a process aimed at obtaining feedback from the activities of organizations and employees (Balouch and Hassan, 2014). An effective employee performance appraisal process is considered crucial as it encourages organizational development and personal growth among employees. An employee is evaluated based on specific criteria associated with their organization's goals and objectives (Awan et al., 2020). Nevertheless, due to the inherent subjectivity in evaluating the performance of employees in many roles, there exist cognitive limitations for evaluators, and a consensus is often lacking regarding the criteria defining 'excellent performance.' Consequently, researchers have shifted their focus towards assessing the fairness of the performance appraisal process. However, performance evaluation routinely encompasses a wide array of quantitative and qualitative factors, along with constraints related to time and resources, evolving tactics and strategies, specialized domain knowledge, information disparities, and entails decision-making amid uncertainty. Furthermore, effective human resources management performance evaluation frequently demands simultaneous consideration of multiple parameters. Thus, the inherent ambiguity prevalent in most human cognition and thought processes also manifests in performance appraisal procedures (İbicioğlu and Ünal, 2014). In many instances, the inability to achieve complete objectivity forces evaluators into a realm of subjectivity, eroding trust in their authority among employees. Nevertheless, it remains imperative for the performance evaluation process to aspire to maximum objectivity to mitigate cognitive confusion and fulfill employee expectations (Obi, 2016).

Fuzzy logic can provide solutions to uncertainties by clustering based on multiple parameters using various fuzzy models, facilitating objective decision-making. Fuzzy models are increasingly prevalent in various scientific fields, particularly in tasks involving decision-making and systems analysis. There has been a significant effort to integrate fuzzy-based decision-making scenarios into the realms of business and management. The utilization of fuzzy decision-making models has been extensively studied across diverse domains, including the employee performance assessment frameworks (Ahmed, 2013; Amini et al., 2016; Milani et al., 2018; Hutahaean et al., 2021), the evaluation of green supply chain management practices (Lin, 2013), food waste treatment method selection (Rani et al., 2021), aircraft training (Wang and Chang, 2007), and identifying critical success factors in emergency management (Zhou et al., 2011).

This study aims to evaluate the performance of warehouse employees working at a spare part company in Turkey, specifically in the city center of Ankara, using fuzzy-based Multi-Criteria Decision Making (MCDM) methods. The primary motivation for this approach is to propose solutions based on multiple criteria in employee performance evaluation. In this context, an analysis was conducted based on the evaluations of three decision-makers involved in the performance evaluation process. The study employs hybrid methods, specifically the PF-AHP and PF-MARCOS methods. With this research, the application of the MCDM approach for employee performance evaluation is introduced to the literature.

Following the introduction, the study includes the conceptual framework and literature review. The method section discusses the steps related to research methods and processes, while the findings are presented in the relevant section. Finally, the results and recommendations are provided in the last section.

2. Literature Review and Criteria Selection

In today's competitive industrial landscape, the efficient management of spare part manufacturing plays a pivotal role in ensuring operational continuity and customer satisfaction. Evaluating the performance of a spare part manufacturing company's employees is a multifaceted task that demands a comprehensive approach. This study delves into the realm of performance appraisal from a multifaceted perspective, employing the PF-AHP-MARCOS methodology. By integrating the Analytic Hierarchy Process (AHP) into the Pythagorean Fuzzy (PF) framework and subsequently applying the MARCOS (Multi-Attribute Rating and Classification of Alternatives by Similarity to an Ideal Solution) method, this study aims to provide a nuanced and robust framework for assessing the performance of spare part manufacturing employees. This approach not only considers multiple criteria but also accommodates the intricacies of the manufacturing domain, offering a holistic view that can lead to more informed decision-making and ultimately enhance the effectiveness of the spare part manufacturing workforce (Lahane and Kant, 2021; Zhou and Chen, 2022; Lahane et al., 2023; Chaurasiya and Jain, 2023; Misra et al. 2023).

Using Pythagorean Fuzzy (PF) sets in Multiple Criteria Decision Making (MCDM) offers several advantages. PF sets excel in handling uncertainty and ambiguity, making them a valuable tool in decision modeling. Unlike traditional crisp sets or fuzzy sets, PF sets provide a triangular membership function that simultaneously considers membership, non-membership, and hesitancy degrees. This nuanced representation of uncertainty allows decision-makers to express preferences and uncertainties more accurately, particularly in situations with imprecise or incomplete information. PF sets are effective in capturing ambiguity and vagueness in decision criteria, which is crucial when dealing with ill-defined boundaries between criteria (Rani et al, 2020). They also offer flexibility in aggregation methods, accommodating a wide range of operators suitable for diverse MCDM scenarios. When integrated with methods like the Analytic Hierarchy Process (AHP) or the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), PF-based approaches can lead to more robust ranking and classification of alternatives, especially in cases involving vague or conflicting criteria. Additionally, PF sets allow for sensitivity analysis, enabling decision-makers to assess the impact of variations in membership, non-membership, and hesitancy levels on decision rankings, contributing to more informed decision-making. Overall, PF sets enhance decision-making by providing a comprehensive and flexible framework for handling uncertainty, ambiguity, and imprecision in MCDM, making them a valuable tool for complex decision scenarios. (Alipour et al, 2021).

The integration of Pythagorean Fuzzy (PF) sets, Analytic Hierarchy Process (AHP), and MARCOS (Multi-Attribute Rating and Classification of Alternatives by Similarity to an Ideal Solution) in Multiple Criteria Decision Making (MCDM) offers a distinct advantage due to the synergies it creates. This combined approach enhances the robustness and effectiveness of the decision-making process, particularly when dealing with intricate decision scenarios. PF sets excel at handling uncertainty and ambiguity, a feature complemented by AHP's systematic criteria weighting. This synergy enables a more comprehensive expression of preferences and facilitates multicriteria evaluation, accommodating varying levels of belief, disbelief, and hesitancy in decision-making (Nguyen et al., 2021). Furthermore, integrating MARCOS enhances the ranking and classification of alternatives based on their similarity to ideal solutions, even when dealing with imprecise criteria and preferences. Sensitivity analysis becomes more accessible with PF sets, aiding in robust decision-making. The flexibility of aggregation methods, improved transparency, and comprehensive decision support further contribute to the advantages of this integrated approach (Mishra et al., 2023). Overall, using PF sets, AHP, and MARCOS together offers a powerful and adaptable framework for addressing the complexities of MCDM, resulting in more informed and reliable decision outcomes.

Table 1. Literature review for evaluation of employee performance.

Study	Methods	Criteria
Kuo and Liang (2012)	VIKOR	"Safety, Comfort, Convenience, Operation, Social Duty"
Islam (2013)	TOPSIS	"Job Knowledge (Possesses skills and knowledge to perform the job competently, Improve ideas to develop the work, Understands and responds prompt to the internal or external clients needs), Communication (Is able to communicate clearly and seeks alternative ways to express his/her ideas Ability to negotiate, using persuasion to convince the others of his/her ideas, Is able to listen, making sure that his understanding is compatible with the other party's speech) Interpersonal Skills (Conflict Resolution, Pleasant manner and treats people with respect, Ethics), Quality (Completes high quality work, Desire to Improve Quality, Self-motivated), Technical and technological knowledge (Has technical knowledge and experience in the related field, Handles working tolls, Proficiency in English)"
Omurca (2014)	Fuzzy C - Means	"Written and unwritten communication skills, non-verbal communication, Administrative orientation, Tolerance for stress, Leadership, Negotiation, Ability to work as part of a team, Reliability and punctuality, Appearance of self confidence, Technical/ professional proficiency, Ability to analyze a situation or problem logically, Planning and organizing, Delegation and control, Work experience, Foreign language, Decision making"
Afshari and Letic (2016)	Fuzzy Logic	"Job knowledge, job quality, initiative and creativity, communication, collaboration, planning and organizational effectiveness, amount of work, and employee absenteeism score."
Kabir et al. (2017)	BBN	"Knowledge & Education (Education Level, Professional Knowledge), Work Performance (Quantity of Work, Quality of Work, Time Management), Leadership & Communication (Teamwork and Cooperation, Leadership, Communication Skills), Interpersonal Skills (Problem Solving, Ethics And Integrity, Confidence, Flexiblity and Versatility, Innovation and Planning)"
Lidinska and Jablonsky (2018)	AHP	"Money and awards, Team, Risk for low performance, Potential"
Mirahmadi, Attafar and Kattabi (2018)	ANP	"Personal Characteristics (Work Ethics, Innovation and Creativity, Analyzing Ability, Reliability), Work Processes (Compliance with Safety Regulations, Compliance of Work Hierarchy, Participate in Group Work, Use of Equipment, Disciplinary Regulations, Ability to Make Decisions, Power of Supervision and Administration), Outcomes (Quantity, Quality, Efficiency, Offering Constructive Suggestions)"
Haq and Ahmed, (2019)	F-TOPSIS	"Job Capability and Knowledge, Prompt Management of Time and Schedule, Machine and Equipment Maintainability, Job efficiency and Perception, Management of Organizational Hierarchy, Professionalism in Attitude, Planning and Leadership capability, Ability to Self-educate and Self-development, Communication skill and team work, Appearance and Outlook, Dependability and Adopting pressure, Job integrity and Work ethics, Innovation and Intuitiveness, Absenteeism"
Nobari et al. (2019)	F-TOPSIS	"Communication skills, technical skills, analysis skills, creativity skills."
Nursari and Murtako (2020)	PROMETHEE	"Diligence, teamwork, sincerity, skills, initiative, independence and absenteeism."

Hutahaean et al. (2022)	SAW	"Level of Education, Experience, Expertise, Collaboration, Quality of Work, Discipline."
Saidin et al. (2022)	F-TOPSIS	"Work Execution, Knowledge and Expertise, Personal Attributes, Contributions other than Office Duties, Quantity of work, Quality of work regarding perfection and neatness, Quality of work regarding efforts and initiatives to attain work perfection, Time management, Work efficacy, Knowledge and expertise in the field of works, Execution of policies, regulation and administrative order, The efficacy of communication, Leadership skills, Ability to organise, Discipline, Proactive and innovative, Connection and collaboration"

Kaynak: Produced by Author.

Table 2. Selected criteria for evaluation of employee performance.

Study	**Methods**	**Criteria**
Work quality (C1)	It refers to the work quality of employee.	Islam, (2013), Afshari and Letic (2016), Kabir et al. (2017), Mirahmadi, Attafar and Kattabi (2018),
Time Management, Attendance and Punctuality (C2)	It refers to the level of time management, attendance and punctuality of employee.	Afshari and Letic (2016), Kabir et al. (2017), Haq and Ahmed (2019), Nursari and Murtako (2020), Saidin (2022)
Machine and Equipment Maintainability (C3)	It refers to level of maintain equipment and machine.	Haq and Ahmed (2019)
Compliance with work hierarchy and work regulations (C4)	It refers to the level of compliance with work hierarchy and work regulations of employee.	Kuo and Liang (2012), Mirahmadi, Attafar and Kattabi (2018), Haq and Ahmed (2019), Sumarno et al. (2021), Saidin (2022)
Communication Skills (C5)	It refers to communication skills of employee.	Omurca (2014), Kabir et al, (2017), Lidinska and Jablonsky (2018), Nobari et al. (2019), Haq and Ahmed (2019),
Teamwork (C6)	It refers to the teamwork performance of employee.	Islam (2013), Hutahaean et al. (2022), Saidin (2022)
Self Education and Development (C7)	It refers to self-education and development level of employee.	Islam (2013), Haq and Ahmed, (2019), Saidin (2022)
Decision Making (C8)	It refers to decision making performance of employee.	Omurca (2014), Mirahmadi, Attafar and Kattabi (2018)

Over a series of research studies, multiple investigators have delved into a range of methodologies aimed at assessing employee performance. Evaluating employee performance necessitates multi-criteria decision-making (MCDM) due to the presence of multiple and conflicting criteria..Various MCDM methods like visekriterijumska optimizacija i kompromisno resenje (VIKOR) (Kuo and Liang, 2012), the technique for order preference by similarity to an ideal solution method (TOPSIS) (Islam, 2013), Fuzzy TOPSIS (Haq and Ahmed, 2019; Saidin, 2022), C-Means (Cluster Means) (Omurca, 2014), Fuzzy Logic (Afshari and Letic, 2016), BBN (Bayesian Belief Network)(Kabir et al.,2017), analytical hierarchical process (AHP) (Lidinska and Jablonsky, 2018), Analytic Network Process (ANP) (Mirahmadi, Attafar and Kattabi, 2018), the preference ranking organisation method for enrichment evaluations (PROMETHEE) (Nursari and Murtako, 2020) and Simple Additive Weighting (SAW) (Hutahaean et al., 2022). Studies conducted on employee performance appraisal are shown in Table 1.

3. Methdology

Pythagorean Fuzzy Sets (PFS), an extended iteration of Atanassov's Intuitionistic Fuzzy Sets (Atanassov, 1986), were introduced by Yager (Yager, 2014). These sets are characterized by their membership, non-membership, and hesitation degrees. Notably, the sum of membership and non-membership degrees can surpass 1, yet the sum of their squares must not exceed 1.

3.1. Preliminaries

Definition 1: Let a set Y be a universe of discourse. A PF set X is an object having the form (Zhang and Xu, 2014):

$$X = \{\langle y, X(\mu_X(y), \vartheta_X(y))\rangle | y \in Y\} \quad (1)$$

where the membership degree $\mu_X(y): y \to [0,1]$ and non-membership degree $\vartheta_X(y): y \to [0,1]$ of element $y \in Y$ to X. And for every $y \in Y$, Eq. (2) is obtained.

$$0 \leq \mu^2{}_X(y) + \vartheta^2{}_X(y) \leq 1 \quad (2)$$

And also the indeterminacy degree of y to X for any PFS X and $y \in Y$ $\pi_X(y)$ is defined as follows:

$$\pi_X(y) = \sqrt{1 - \mu^2{}_X(y) + \vartheta^2{}_X(y)} \quad (3)$$

Definition 2: If $A_1 = X(\mu_{A_1}, \vartheta_{A_1})$ and $A_2 = X(\mu_{A_2}, \vartheta_{A_2})$ are the PF numbers, $\gamma > 0$, the operations on A_1 and A_2 are defined as follows (Zhang and Xu, 2014; Zeng et al., 2016):

$$A_1 \oplus A_2 = X\left(\sqrt{\mu^2{}_{A_1} + \mu^2{}_{A_2} - \mu^2{}_{A_1}\mu^2{}_{A_2}}, \vartheta_{A_1}\vartheta_{A_2}\right) \quad (4)$$

$$A_1 \otimes A_2 = X\left(\mu_{A_1}\mu_{A_2}, \sqrt{\vartheta^2{}_{A_1} + \vartheta^2{}_{A_2} - \vartheta^2{}_{A_1}\vartheta^2{}_{A_2}}\right) \quad (5)$$

$$\gamma A_1 = X\left(\sqrt{1-\left(1-\mu^2{}_{A_1}\right)^{\gamma}}, \vartheta^{\gamma}{}_{A_1}\right) \quad (6)$$

$$A^{\gamma}{}_1 = X\left(\mu^{\gamma}{}_{A_1}, \sqrt{1-\left(1-\vartheta^2{}_{A_1}\right)^{\gamma}}\right) \quad (7)$$

Definition 3: The interval-valued PF weighted geometric (IVPFWG) operator is used to combine the criteria evaluations made by more than one decision maker. This operation is represented by Eq. (8). $A_i = [\mu_i^L, \mu_i^U], [\vartheta_i^L, \vartheta_i^U]$ is an interval-valued PF number. n is the number of decision maker and w_j is the weight of the criteria. And $\sum_{j=1}^{n} w_j = 1$ (Peng and Yang, 2016).

$$IVPFWG(A_1, A_2, \dots, A_n) = \left[\prod_{j=1}^{n}\left(\mu_{a_j}^L\right)^{w_j}, \prod_{j=1}^{n}\left(\mu_{a_j}^U\right)^{w_j}\right], \left[\prod_{j=1}^{n}\left(\vartheta_{a_j}^L\right)^{w_j}, \prod_{j=1}^{n}\left(\vartheta_{a_j}^U\right)^{w_j}\right] \quad (8)$$

3.2. PF AHP

Saaty's AHP method (Saaty, 2005) involves a pairwise comparison of criteria by decision-makers. AHP, being one of the most established and widely used multi-criteria decision-making techniques, finds applications across various domains. The synergy between Pythagorean Fuzzy (PF) and the Analytic Hierarchy Process (AHP) in Multiple Criteria Decision Making (MCDM) brings forth a range of complementary strengths, enriching the decision-making process. This integration enhances decision-making through the provision of a more precise means of representing uncertainties and preferences. PF sets excel at capturing and quantifying uncertainty and vagueness, making them a valuable addition to the structured AHP framework. The combination allows decision-makers to express preferences in greater detail, considering different degrees of belief, disbelief, and hesitancy. Additionally, this approach handles complex relationships among criteria and alternatives, enhancing the modeling of intricate interdependencies. Sensitivity analysis becomes more accessible, providing insights into decision robustness (Shahzad and Abdul,2022). The transparency and clarity of the resulting decision models make it easier for stakeholders to comprehend and validate the decision process. The flexibility in aggregation methods ensures adaptability to various decision scenarios, ultimately empowering decision-makers to make well-informed and defensible choices. In summary, the synergy between PF sets and AHP enhances MCDM by providing a more accurate, flexible, and comprehensive decision-making framework. The steps of PF-AHP methods developed by Ilbahar et al. are explained below (Ilbahar et al., 2018):

Table 3. Weighting scale for the interval-valued PF-AHP method

Linguistic Terms	Interval-valued PF numbers			
	μ_L	μ_U	ϑ_L	ϑ_U
Extremely Low / 1	0	0	0.900	1.000
Very Low / 2	0.100	0.200	0.800	0.900
Low / 3	0.200	0.350	0.650	0.800
Below Average / 4	0.350	0.450	0.550	0.650
Average / 5	0.450	0.550	0.450	0.550
Above Average / 6	0.550	0.650	0.350	0.450
High / 7	0.650	0.800	0.200	0.350
Very High / 8	0.800	0.900	0.100	0.200
Extremely High/ 9	0.900	1.000	0	0
Exactly Equal / 10	0.196	0.196	0.196	0.190

Step 1-1: The criteria are evaluated by the decision makers using Table-3 and the decision matrix $(x_{ij})_{mxn}$ is created.

Step 1-2: The differences between the upper and lower values of the membership and non-membership functions is calculated by using Eq. (9) and Eq. (10).

$$d_{ij_L} = \mu^2{}_{ij_L} - \vartheta^2{}_{ij_U} \quad (9)$$

$$d_{ij_U} = \mu^2{}_{ij_U} - \vartheta^2{}_{ij_L} \quad (10)$$

Step 1-3: Calculate the interval multiplicative values by using Eq. (11) and Eq. (12).

$$S_{ij_L} = \sqrt{1000^{d_L}} \quad (11)$$

$$S_{ij_U} = \sqrt{1000^{d_U}} \quad (12)$$

Step 1-4: Calculate the determinacy values by using Eq. (13).

$$\tau_{ij} = 1 - \left(\mu^2{}_{ij_U} - \mu^2{}_{ij_L}\right) - \left(\vartheta^2{}_{ij_U} - \vartheta^2{}_{ij_L}\right) \quad (13)$$

Step 1-5: Multiply the interval multiplicative matrix by the determinacy values to obtain the weight matrix by using Eq. (14).

$$t_{ij} = \left(\frac{S_{ij_L} + S_{ij_U}}{2}\right) * \tau_{ij} \quad (14)$$

Step 1-6: The weight matrix is normalised to determine the criteria weights. Eq. (15) is used for this.

$$\omega_j = \frac{\sum_{j=1}^{n} t_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}} \quad (15)$$

3.3. PF MARCOS

The MARCOS model identifies the best alternative as the one closest to the ideal solution (IS) while being farthest from the anti-ideal solution (AIS). Combining Pythagorean Fuzzy (PF) sets with the MARCOS (Multi-Attribute Rating and Classification of Alternatives by Similarity to an Ideal Solution) framework brings about numerous benefits within the realm of Multiple Criteria Decision Making (MCDM). This integration enhances the decision-making process by adeptly handling the uncertainties and ambiguities inherent in decision criteria. PF sets excel in handling uncertainty and ambiguity, especially when dealing with vague or uncertain criteria and preferences (Mishra et al., 2023). When combined with MARCOS, this approach improves the accuracy of ranking and classifying alternatives based on their similarity to ideal solutions. It also enhances transparency in decision models, making it easier for stakeholders to understand and trust the process. Sensitivity analysis becomes more accessible, providing insights into decision robustness. The flexibility in aggregation methods allows for adaptation to various decision scenarios. Briefly, the synergy between PF sets and MARCOS enhances MCDM by providing a more precise, transparent, and adaptable decision-making framework, particularly valuable in complex and uncertain decision contexts. The steps of this method are described below (Chaurasiya & Jain 2023).

Step 2-1: Each alternative is evaluated by the decision makers according to the criteria according to Table-4.

Table 4. Evaluation of Alternatives by The Decision Makers

Linguistic Terms	Abbreviation	PFNs
Exceptional	EX	(0.9800, 0.2000)
Excellent	EL	(0.8700, 0.3500)
Very good	VG	(0.7000, 0.4000)
Good	G	(0.6500, 0.4500)
Satisfactory	S	(0.5000, 0.5500)
Acceptable	A	(0.4000, 0.7000)
Partially Acceptable	PA	(0.3600, 0.8000)
Insufficient	I	(0.2500, 0.8700)
Very Insufficient	VI	(0.2000, 0.9800)

Step 2-2: The assessments made by decision makers are combined with Eq. (16). λ_k is the weight of the kth decision maker.

$$\varepsilon_{ij} = \left(\sqrt{1 - \Pi_{k=1}^{l}(1 - \mu^2{}_k)^{\lambda_k}}, \Pi_{k=1}^{l}(\vartheta^2{}_k)^{\lambda_k}\right) \quad (16)$$

Step 2-3: The ideal and anti-ideal solutions for the benefit and cost criteria are calculated by Eq. (17) and Eq. (18) (P_b, benefit criteria; P_c, cost criteria).

$$I_{IS} = \max_j(\varepsilon_{ij}) \text{ if } j \in P_b \text{ and } I_{IS} = \min_j(\varepsilon_{ij}) \text{ if } j \in P_c \quad (17)$$

$$I_{AIS} = \min_j(\varepsilon_{ij}) \text{ if } j \in P_b \text{ and } I_{AIS} = \max_j(\varepsilon_{ij}) \text{ if } j \in P_c \quad (18)$$

Step 2-4: The decision matrix is normalised by Eq (19) and Eq. (20).

$$\varepsilon'_{ij} = \frac{x_{(IS)_i}}{x_{ij}}, \text{ for cost criteria} \tag{19}$$

$$\varepsilon'_{ij} = \frac{x_{ij}}{x_{(IS)_i}}, \text{ for benefit criteria} \tag{20}$$

Step 2-5: The decision matrix is weighted by Eq. (28).

$$\delta_{ij} = \varepsilon'_{ij} * \omega_j \tag{21}$$

Step 2-6: The utility function associated with the ideal and anti-ideal solution is calculated by Eq. (22) and Eq. (23).

$$f(\Psi_i^+) = \frac{\Psi_i^-}{\Psi_i^+ + \Psi_i^-} \tag{22}$$

$$f(\Psi_i^-) = \frac{\Psi_i^+}{\Psi_i^+ + \Psi_i^-} \tag{23}$$

Step 2-7: The utility functions of the alternatives are calculated by Eq. (24).

$$f(\Psi_i) = \frac{\Psi_i^+ + \Psi_i^-}{1 + \frac{1-f(\Psi_i^+)}{f(\Psi_i^+)} + \frac{1-f(\Psi_i^-)}{f(\Psi_i^-)}} \tag{24}$$

Step 2-8: The ranking of the alternatives is formed with the $f(\Psi_i)$ values obtained. The alternative with the highest value is determined as the best alternative.

4. Case Study for Performance Evaluation of Spare Part Company's Employee Performance

This study employs PF-AHP and PF-MARCOS as hybrid approaches. The incorporation of Pythagorean Fuzzy (PF) sets in the context of Multiple Criteria Decision Making (MCDM), alongside both MARCOS (Multi-Attribute Rating and Classification of Alternatives by Similarity to an Ideal Solution) and Analytic Hierarchy Process (AHP), brings forth several notable advantages. Firstly, it provides an effective solution for managing and tackling uncertainty and imprecision, which are common challenges in decision-making processes. PF sets excel at capturing these uncertainties and complement both MARCOS and AHP, offering a comprehensive framework for addressing them. Secondly, this approach enables decision-makers to articulate their preferences in a more nuanced and detailed manner, encompassing various levels of membership, non-membership, and hesitancy. Thirdly, PF sets exhibit high adaptability, accommodating both qualitative and quantitative data, thereby enhancing the overall flexibility of the decision model. Furthermore, it enhances the transparency of decision models, facilitating stakeholders' comprehension and endorsement of the decision-making process. Additionally, the integration with MARCOS enhances the accuracy of ranking and classifying alternatives based on their similarity to ideal solutions, contributing to more dependable decision outcomes. AHP's structured criteria weighting method complements the flexibility of PF sets, ensuring a systematic assessment of criterion importance. Sensitivity analysis is facilitated, providing insights into decision robustness. In essence, the combination of PF sets with both MARCOS and AHP creates a holistic and adaptable decision support framework, well-suited for addressing complex decision scenarios and uncertainties in MCDM (Nguyen et al.,2022; Mishra et al., 2023).

In general performance evaluation processes in spare part company, the importance of human resources comes to the fore due to human-oriented activities. The performance of all employees and consequently of all processes is important for the company's competitiveness. Therefore, the purpose of this study is to assess how well the company employees perform. Eight criteria were established in this situation as a consequence of the literature study: Work quality (C1), Time Management, Attendance and Punctuality (C2), Machine and Equipment Maintainability (C3), Compliance with work hierarchy and work regulations (C4), Communication Skills (C5), Teamwork (C6), Self Education and Development (C7), Decision Making (C8). These criteria were also found appropriate by company's senior managers.

In this case study, the company conducts a performance evaluation to select the "Employee of the Month". "Employee of the Month" is selected to recognize and reward individuals within an organization or community who have demonstrated outstanding performance or made significant contributions during a given period. This selection is made to recognize outstanding performance, motivate employees or members, inspire others and encourage positive behavior. Furthermore, such a selection can promote a sense of unity among employees or members and increase their commitment to the organization or society. "Employee of the Month" selection helps to highlight what outstanding performance looks like and can encourage others to strive for better performance. It also makes employees or members feel valued by providing an opportunity to recognize individuals' contributions and express their gratitude. For this purpose, the performance of the employees (A1, A2, A3, A4, A5) of a spare part company operating Ankara was analyzed by three experts (DM-1, DM-2, DM-3) assigned to the performance evaluation of the head office. Findings were obtained by applying all the steps described in the methodology section in order.

Step 1-1: The criteria comparisons made by the decision makers are shown in Table-5 and their representation with PF numbers is shown in Table-6.

Table 5. The Criteria Comparisons Made by The Decision Makers

		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
DM-1	C1	10	4	7	6	6	7	8	6
	C2	6	10	8	8	7	7	8	7
	C3	3	2	10	6	4	5	5	4
	C4	4	2	4	10	4	6	6	5
	C5	4	3	6	6	10	5	6	6
	C6	3	3	5	4	5	10	7	5
	C7	2	2	5	4	4	3	10	4
	C8	4	3	6	5	4	5	6	10
		C1	C2	C3	C4	C5	C6	C7	C8
DM-2	C1	10	7	7	6	6	7	8	6
	C2	3	10	4	4	4	6	7	4
	C3	3	6	10	3	3	4	6	4
	C4	4	6	7	10	6	7	8	6
	C5	4	6	7	4	10	6	7	6
	C6	3	4	6	3	4	10	6	4
	C7	2	3	4	2	3	4	10	3
	C8	4	6	6	4	4	6	7	10
		C1	C2	C3	C4	C5	C6	C7	C8
DM-3	C1	10	6	8	6	6	6	8	7
	C2	4	10	7	4	4	4	7	6
	C3	2	3	10	3	3	3	6	4
	C4	4	6	7	10	5	4	8	6
	C5	4	6	7	5	10	4	8	6
	C6	4	6	7	6	6	10	8	7
	C7	2	3	4	2	2	2	10	3
	C8	3	4	6	4	4	3	7	10

Table 6. The Criteria Comparisons Made by The Decision Makers Representate with PF Numbers

		C1				**C2**				**C3**			
	C1	0,196	0,196	0,196	0,190	0,350	0,450	0,550	0,650	0,650	0,800	0,200	0,350
	C2	0,550	0,650	0,350	0,450	0,196	0,196	0,196	0,190	0,800	0,900	0,100	0,200
	C3	0,200	0,350	0,650	0,800	0,100	0,200	0,800	0,900	0,196	0,196	0,196	0,190
	C4	0,350	0,450	0,550	0,650	0,100	0,200	0,800	0,900	0,350	0,450	0,550	0,650
	C5	0,350	0,450	0,550	0,650	0,200	0,350	0,650	0,800	0,550	0,650	0,350	0,450
	C6	0,200	0,350	0,650	0,800	0,200	0,350	0,650	0,800	0,450	0,550	0,450	0,550
	C7	0,100	0,200	0,800	0,900	0,100	0,200	0,800	0,900	0,450	0,550	0,450	0,550
	C8	0,350	0,450	0,550	0,650	0,200	0,350	0,650	0,800	0,550	0,650	0,350	0,450
		C4				C5				C6			
	C1	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C2	0,800	0,900	0,100	0,200	0,650	0,800	0,200	0,350	0,650	0,800	0,200	0,350
	C3	0,550	0,650	0,350	0,450	0,350	0,450	0,550	0,650	0,450	0,550	0,450	0,550
DM-1	C4	0,196	0,196	0,196	0,190	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450
	C5	0,550	0,650	0,350	0,450	0,196	0,196	0,196	0,190	0,450	0,550	0,450	0,550
	C6	0,350	0,450	0,550	0,650	0,450	0,550	0,450	0,550	0,196	0,196	0,196	0,190
	C7	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,200	0,350	0,650	0,800
	C8	0,450	0,550	0,450	0,550	0,350	0,450	0,550	0,650	0,450	0,550	0,450	0,550
		C7				C8							
	C1	0,800	0,900	0,100	0,200	0,550	0,650	0,350	0,450				
	C2	0,800	0,900	0,100	0,200	0,650	0,800	0,200	0,350				
	C3	0,450	0,550	0,450	0,550	0,350	0,450	0,550	0,650				
	C4	0,550	0,650	0,350	0,450	0,450	0,550	0,450	0,550				
	C5	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450				
	C6	0,650	0,800	0,200	0,350	0,450	0,550	0,450	0,550				
	C7	0,196	0,196	0,196	0,190	0,350	0,450	0,550	0,650				
	C8	0,550	0,650	0,350	0,450	0,196	0,196	0,196	0,190				

		C1				C2				C3			
	C1	0,196	0,196	0,196	0,190	0,650	0,800	0,200	0,350	0,650	0,800	0,200	0,350
	C2	0,200	0,350	0,650	0,800	0,196	0,196	0,196	0,190	0,350	0,450	0,550	0,650
	C3	0,200	0,350	0,650	0,800	0,550	0,650	0,350	0,450	0,196	0,196	0,196	0,190
	C4	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C5	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C6	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450
	C7	0,100	0,200	0,800	0,900	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650
	C8	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450
		C4				C5				C6			
	C1	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C2	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450
	C3	0,200	0,350	0,650	0,800	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650
DM-2	C4	0,196	0,196	0,196	0,190	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C5	0,350	0,450	0,550	0,650	0,196	0,196	0,196	0,190	0,550	0,650	0,350	0,450
	C6	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650	0,196	0,196	0,196	0,190
	C7	0,100	0,200	0,800	0,900	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650
	C8	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450
		C7				C8							
	C1	0,800	0,900	0,100	0,200	0,550	0,650	0,350	0,450				
	C2	0,650	0,800	0,200	0,350	0,350	0,450	0,550	0,650				
	C3	0,550	0,650	0,350	0,450	0,350	0,450	0,550	0,650				
	C4	0,800	0,900	0,100	0,200	0,550	0,650	0,350	0,450				
	C5	0,650	0,800	0,200	0,350	0,550	0,650	0,350	0,450				
	C6	0,550	0,650	0,350	0,450	0,350	0,450	0,550	0,650				
	C7	0,196	0,196	0,196	0,190	0,200	0,350	0,650	0,800				
	C8	0,650	0,800	0,200	0,350	0,196	0,196	0,196	0,190				

		C1				C2				C3			
	C1	0,196	0,196	0,196	0,190	0,550	0,650	0,350	0,450	0,800	0,900	0,100	0,200
	C2	0,350	0,450	0,550	0,650	0,196	0,196	0,196	0,190	0,650	0,800	0,200	0,350
	C3	0,100	0,200	0,800	0,900	0,200	0,350	0,650	0,800	0,196	0,196	0,196	0,190
	C4	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C5	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C6	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450	0,650	0,800	0,200	0,350
	C7	0,100	0,200	0,800	0,900	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650
	C8	0,200	0,350	0,650	0,800	0,350	0,450	0,550	0,650	0,550	0,650	0,350	0,450
		C4				C5				C6			
	C1	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450
	C2	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650
	C3	0,200	0,350	0,650	0,800	0,200	0,350	0,650	0,800	0,200	0,350	0,650	0,800
DM-3	C4	0,196	0,196	0,196	0,190	0,450	0,550	0,450	0,550	0,350	0,450	0,550	0,650
	C5	0,450	0,550	0,450	0,550	0,196	0,196	0,196	0,190	0,350	0,450	0,550	0,650
	C6	0,550	0,650	0,350	0,450	0,550	0,650	0,350	0,450	0,196	0,196	0,196	0,190
	C7	0,100	0,200	0,800	0,900	0,100	0,200	0,800	0,900	0,100	0,200	0,800	0,900
	C8	0,350	0,450	0,550	0,650	0,350	0,450	0,550	0,650	0,200	0,350	0,650	0,800
		C7				C8							
	C1	0,800	0,900	0,100	0,200	0,650	0,800	0,200	0,350				
	C2	0,650	0,800	0,200	0,350	0,550	0,650	0,350	0,450				
	C3	0,550	0,650	0,350	0,450	0,350	0,450	0,550	0,650				
	C4	0,800	0,900	0,100	0,200	0,550	0,650	0,350	0,450				
	C5	0,800	0,900	0,100	0,200	0,550	0,650	0,350	0,450				
	C6	0,800	0,900	0,100	0,200	0,650	0,800	0,200	0,350				
	C7	0,196	0,196	0,196	0,190	0,200	0,350	0,650	0,800				
	C8	0,650	0,800	0,200	0,350	0,196	0,196	0,196	0,190				

Step 1-2: Differences between the lower and upper values of membership and non-membership functions the differences between the lower and upper values of membership and non-membership functions calculated using Equation (9) and Equation (10) are given in Table-7.

Table 7. Differences Between the Lower and Upper Values of Membership and Non-Membership

	C1		C2		C3		C4	
	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}
C1	0,002	0,000	0,031	0,266	0,401	0,667	0,100	0,300
C2	-0,266	-0,031	0,002	0,000	0,194	0,422	0,020	0,224
C3	-0,667	-0,401	-0,422	-0,194	0,002	0,000	-0,358	-0,095
C4	-0,300	-0,100	-0,224	-0,020	0,095	0,358	0,002	0,000
C5	-0,300	-0,100	-0,143	0,095	0,233	0,499	-0,100	0,100
C6	-0,499	-0,233	-0,266	-0,031	0,100	0,334	-0,266	-0,031
C7	-0,800	-0,600	-0,667	-0,401	-0,233	-0,033	-0,629	-0,430
C8	-0,401	-0,167	-0,266	-0,031	0,100	0,300	-0,233	-0,033

	C5		C6		C7		C8	
	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}	d_{ij_L}	d_{ij_U}
C1	0,100	0,300	0,233	0,499	0,600	0,800	0,167	0,401
C2	-0,095	0,143	0,031	0,266	0,401	0,667	0,031	0,266
C3	-0,499	-0,233	-0,334	-0,100	0,033	0,233	-0,300	-0,100
C4	-0,100	0,100	0,031	0,266	0,430	0,629	0,033	0,233
C5	0,002	0,000	-0,100	0,100	0,334	0,566	0,100	0,300
C6	-0,100	0,100	0,002	0,000	0,334	0,566	-0,031	0,205
C7	-0,566	-0,334	-0,566	-0,334	0,002	0,000	-0,499	-0,233
C8	-0,300	-0,100	-0,205	0,031	0,233	0,499	0,002	0,000

Step 1-3: The range product values calculated using Equation (11) and Equation (12) are given in Table 8.

Table 8. Calculated Range Product Values

	C1		C2		C3		C4	
	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}
C1	1,008	1,000	1,114	2,504	3,993	10,014	1,413	2,818
C2	0,399	0,897	1,008	1,000	1,952	4,299	1,072	2,170
C3	0,100	0,250	0,233	0,512	1,008	1,000	0,291	0,721
C4	0,355	0,708	0,461	0,933	1,386	3,439	1,008	1,000
C5	0,355	0,708	0,610	1,386	2,237	5,607	0,708	1,413
C6	0,178	0,447	0,399	0,897	1,413	3,173	0,399	0,897
C7	0,063	0,126	0,100	0,250	0,447	0,892	0,114	0,227
C8	0,250	0,562	0,399	0,897	1,413	2,818	0,447	0,892

	C5		C6		C7		C8	
	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}	S_{ij_L}	S_{ij_U}
C1	1,413	2,818	2,237	5,607	7,943	15,849	1,780	3,993
C2	0,721	1,639	1,114	2,504	3,993	10,014	1,114	2,504
C3	0,178	0,447	0,315	0,708	1,121	2,237	0,355	0,708
C4	0,708	1,413	1,114	2,504	4,413	8,779	1,121	2,237
C5	1,008	1,000	0,708	1,413	3,173	7,068	1,413	2,818
C6	0,708	1,413	1,008	1,000	3,173	7,068	0,897	2,029
C7	0,141	0,315	0,141	0,315	1,008	1,000	0,178	0,447
C8	0,355	0,708	0,493	1,114	2,237	5,607	1,008	1,000

Step 1-4: The determination values calculated using Equation (13) are given in Table-9.

Table 9. The Determinated Values

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1,002	0,766	0,734	0,800	0,800	0,734	0,800	0,766
C2	0,766	1,002	0,771	0,796	0,762	0,766	0,734	0,766
C3	0,734	0,771	1,002	0,737	0,734	0,766	0,800	0,800
C4	0,800	0,796	0,737	1,002	0,800	0,766	0,801	0,800
C5	0,800	0,762	0,734	0,800	1,002	0,800	0,768	0,800
C6	0,734	0,766	0,766	0,766	0,800	1,002	0,768	0,764
C7	0,800	0,734	0,800	0,801	0,768	0,768	1,002	0,734
C8	0,766	0,766	0,800	0,800	0,800	0,764	0,734	1,002

Step 1-5: The weight matrix obtained using Equation (14) is given in Table 10.

Table 10. The Weighted Matrix

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1,006	1,385	5,139	1,692	1,692	2,879	9,517	2,211
C2	0,496	1,006	2,411	1,290	0,900	1,385	5,139	1,385
C3	0,129	0,287	1,006	0,373	0,229	0,392	1,343	0,425
C4	0,425	0,555	1,778	1,006	0,848	1,385	5,283	1,343
C5	0,425	0,761	2,879	0,848	1,006	0,848	3,933	1,692
C6	0,229	0,496	1,756	0,496	0,848	1,006	3,933	1,118
C7	0,076	0,129	0,536	0,136	0,175	0,175	1,006	0,229
C8	0,311	0,496	1,692	0,536	0,425	0,614	2,879	1,006

Step 1-6: The criteria weights obtained are shown in Table 11.

Table 11. The Criteria Weights

	C1	C2	C3	C4	C5	C6	C7	C8
ω_j	0,2866	0,1574	0,0470	0,1418	0,1392	0,1110	0,0277	0,0894

Step 2-1: The alternatives linguistically evaluated by the decision makers according to each criterion and the PF number values of these evaluations are given in Tables 12 and 13, respectively.

Table 12. Alternatives Linguistically Evaluated by The Decision Makers According to Each Criterion

		C1	C2	C3	C4	C5	C6	C7	C8
A1	DM-1	PA	A	A	S	A	S	G	S
	DM-2	A	A	A	G	S	PA	A	S
	DM-3	S	A	S	G	S	S	G	G
A2	DM-1	G	G	G	VG	G	S	S	G
	DM-2	G	VG	VG	G	G	G	VG	VG
	DM-3	VG	VG	G	VG	VG	G	G	VG
A3	DM-1	VG	G	G	G	S	S	G	G
	DM-2	G	G	G	VG	VG	G	G	G
	DM-3	S	G	S	G	G	S	S	G
A4	DM-1	VG	EL	EL	VG	VG	G	VG	VG
	DM-2	VG	VG	EL	EL	VG	VG	G	VG
	DM-3	EL	EL	EL	VG	VG	G	VG	EL
A5	DM-1	S	PA	PA	S	S	A	PA	PA
	DM-2	G	S	A	A	A	PA	A	S
	DM-3	G	G	S	G	S	S	A	A

Table 13. The PF Number Values of Evaluations.

		C1		C2		C3		C4	
A1	DM-1	0,3600	0,8000	0,4000	0,7000	0,4000	0,7000	0,5000	0,5500
	DM-2	0,4000	0,7000	0,4000	0,7000	0,4000	0,7000	0,6500	0,4500
	DM-3	0,5000	0,5500	0,4000	0,7000	0,5000	0,5500	0,6500	0,4500
A2	DM-1	0,6500	0,4500	0,6500	0,4500	0,6500	0,4500	0,7000	0,4000
	DM-2	0,6500	0,4500	0,7000	0,4000	0,7000	0,4000	0,6500	0,4500
	DM-3	0,7000	0,4000	0,7000	0,4000	0,6500	0,4500	0,7000	0,4000
A3	DM-1	0,7000	0,4000	0,6500	0,4500	0,6500	0,4500	0,6500	0,4500
	DM-2	0,6500	0,4500	0,6500	0,4500	0,6500	0,4500	0,7000	0,4000
	DM-3	0,5000	0,5500	0,6500	0,4500	0,5000	0,5500	0,6500	0,4500
A4	DM-1	0,7000	0,4000	0,8700	0,3500	0,8700	0,3500	0,7000	0,4000
	DM-2	0,7000	0,4000	0,7000	0,4000	0,8700	0,3500	0,8700	0,3500
	DM-3	0,8700	0,3500	0,8700	0,3500	0,8700	0,3500	0,7000	0,4000
A5	DM-1	0,5000	0,5500	0,3600	0,8000	0,3600	0,8000	0,5000	0,5500
	DM-2	0,6500	0,4500	0,5000	0,5500	0,4000	0,7000	0,4000	0,7000
	DM-3	0,6500	0,4500	0,6500	0,4500	0,5000	0,5500	0,6500	0,4500
		C5		**C6**		**C7**		**C8**	
A1	DM-1	0,4000	0,7000	0,5000	0,5500	0,6500	0,4500	0,5000	0,5500
	DM-2	0,5000	0,5500	0,3600	0,8000	0,4000	0,7000	0,5000	0,5500
	DM-3	0,5000	0,5500	0,5000	0,5500	0,6500	0,4500	0,6500	0,4500
A2	DM-1	0,6500	0,4500	0,5000	0,5500	0,5000	0,5500	0,6500	0,4500
	DM-2	0,6500	0,4500	0,6500	0,4500	0,7000	0,4000	0,7000	0,4000
	DM-3	0,7000	0,4000	0,6500	0,4500	0,6500	0,4500	0,7000	0,4000
A3	DM-1	0,5000	0,5500	0,5000	0,5500	0,6500	0,4500	0,6500	0,4500
	DM-2	0,7000	0,4000	0,6500	0,4500	0,6500	0,4500	0,6500	0,4500
	DM-3	0,6500	0,4500	0,5000	0,5500	0,5000	0,5500	0,6500	0,4500
A4	DM-1	0,7000	0,4000	0,6500	0,4500	0,7000	0,4000	0,7000	0,4000
	DM-2	0,7000	0,4000	0,7000	0,4000	0,6500	0,4500	0,7000	0,4000
	DM-3	0,7000	0,4000	0,6500	0,4500	0,7000	0,4000	0,8700	0,3500
A5	DM-1	0,5000	0,5500	0,4000	0,7000	0,3600	0,8000	0,3600	0,8000
	DM-2	0,4000	0,7000	0,3600	0,8000	0,4000	0,7000	0,5000	0,5500
	DM-3	0,5000	0,5500	0,5000	0,5500	0,4000	0,7000	0,4000	0,7000

Step 2-2: The combined decision matrix is in Table 14.

Table 14. The Combined Decision Matrix

	C1		C2		C3		C4	
A1	0,4260	0,6753	0,4000	0,7000	0,4372	0,6459	0,6082	0,4811
A2	0,6678	0,4327	0,6844	0,4160	0,6678	0,4327	0,6844	0,4160
A3	0,6289	0,4626	0,6500	0,4500	0,6082	0,4811	0,6678	0,4327
A4	0,7756	0,3826	0,8299	0,3659	0,8700	0,3500	0,7756	0,3826
A5	0,6082	0,4811	0,5269	0,5828	0,4260	0,6753	0,5349	0,5575
	C5		**C6**		**C7**		**C8**	
A1	0,4702	0,5960	0,4603	0,6232	0,5879	0,5214	0,5591	0,5144
A2	0,6678	0,4327	0,6082	0,4811	0,6289	0,4626	0,6844	0,4160
A3	0,6289	0,4626	0,5591	0,5144	0,6082	0,4811	0,6500	0,4500
A4	0,7000	0,4000	0,6678	0,4327	0,6844	0,4160	0,7756	0,3826
A5	0,4702	0,5960	0,4260	0,6753	0,3873	0,7319	0,4260	0,6753

Step 2-3: The ideal and anti-ideal solutions calculated by Equation (17) and Equation (18) are shown in Table 15.

Table 15. The Ideal and Anti-Ideal Solutions.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0,2350	0,2139	0,2504	0,4113	0,2840	0,2701	0,3847	0,3646
A2	0,4759	0,4958	0,4759	0,4958	0,4759	0,4113	0,4334	0,4958
A3	0,4334	0,4553	0,4113	0,4759	0,4334	0,3646	0,4113	0,4553
A4	0,6047	0,6795	0,7410	0,6047	0,5150	0,4759	0,4958	0,6047
A5	0,4113	0,3231	0,2350	0,3358	0,2840	0,2350	0,1967	0,2350
I_{IS}	0,6047	0,6795	0,7410	0,6047	0,5150	0,4759	0,4958	0,6047
I_{AIS}	0,2350	0,2139	0,2350	0,3358	0,2840	0,2350	0,1967	0,2350

Step 2-4: The normalised decision matrix calculated by Eq (19) and Eq (20) is shown in Table 16.

Table 16. The Normalised Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0,3886	0,3148	0,3379	0,6802	0,5514	0,5675	0,7760	0,6029
A2	0,7870	0,7296	0,6422	0,8199	0,9240	0,8643	0,8741	0,8199
A3	0,7167	0,6699	0,5550	0,7870	0,8414	0,7661	0,8296	0,7529
A4	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
A5	0,6802	0,4755	0,3171	0,5554	0,5514	0,4937	0,3968	0,3886
I_{IS}	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
I_{AIS}	0,3886	0,3148	0,3171	0,5554	0,5514	0,4937	0,3968	0,3886

Step 2-5: The weighted decision matrix calculated by Equation (28) is shown in Table 17.

Table 17. Selected criteria for evaluation of employee performance.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0,1114	0,0495	0,0159	0,0964	0,0767	0,0630	0,0215	0,0539
A2	0,2256	0,1148	0,0302	0,1162	0,1286	0,0959	0,0242	0,0733
A3	0,2054	0,1054	0,0261	0,1116	0,1171	0,0850	0,0229	0,0673
A4	0,2866	0,1574	0,0470	0,1418	0,1392	0,1110	0,0277	0,0894
A5	0,1950	0,0748	0,0149	0,0787	0,0767	0,0548	0,0110	0,0347

Step 2-6,7 and 8: The calculated utility functions associated with the ideal and anti-ideal solution, the utility functions of the alternatives and the ranking of the alternatives are given in Table 18.

Table 18. The Ranking of The Alternatives

	Ψ_i^+	Ψ_i^-	$f(\Psi_i^+)$	$f(\Psi_i^-)$	$f(\Psi_i)$	Rankings
A1	0,4883	1,1309	0,6984	0,3016	0,4320	5
A2	0,8088	1,8731	0,6984	0,3016	0,7156	2
A3	0,7409	1,7158	0,6984	0,3016	0,6555	3
A4	1,0000	2,3159	0,6984	0,3016	0,8848	1
A5	0,5407	1,2522	0,6984	0,3016	0,4784	4

5. Results and Discussion

The innovative PF-AHP-MARCOS approach presented in this study offers a robust framework for evaluating warehouse employees’ performance in Turkey. With the use of PF-AHP and PF-MARCOS methods together, it offers a more effective and flexible approach when dealing with complex and multidimensional decision-making problems. In addition, many advantages can be achieved by using these two methods together. PF-AHP performs weighted sequencing evaluation, while PF-MARCOS is used to manage complex solutions and balance the preferences of different stakeholders. Both methods aim to comprehensively evaluate different criteria and objectives. By using these two methods together, the criteria can be evaluated more comprehensively. Both PF-AHP and PF-MARCOS methods aim to better handle uncertainty using the Pythagorean Fuzzy approach. The combined use of the two methods helps to obtain more realistic results in real-world complex decision-making problems. The decision making problem may involve conflicting objectives. PF-AHP balances various objectives and decision makers' preferences, while PF-MARCOS addresses these contradictions when weighting and ranking. The combination of these two methods allows to effectively balance conflicting objectives. Objective and subjective factors influencing management decisions often have to come together. The combination of these two methods effectively combines both quantitative and qualitative data, providing a more comprehensive assessment. The combined use of PF-AHP and PF-MARCOS offers decision makers more information and perspective. This helps to make better-informed and smarter decisions. Both methods offer a wide range of applications. When used in combination, they can be applied to complex decision-making problems in different industries and fields. In addition, when these two methods are used together, they support the evaluation of employees at both strategic and tactical levels. By amalgamating the power of PF-AHP and PF-MARCOS, this method addresses the intricate challenges associated with performance assessment, incorporating diverse perspectives and objective metrics. The structured and iterative nature of the approach facilitates the identification of high-performing employees and emphasizes the significance of factors such as work quality. As this study demonstrates, the tailored alignment of evaluation processes with Turkey's cultural and business context through the PF-AHP-MARCOS framework can provide organizations with a comprehensive understanding of employees' abilities and potential contributions.

In this study, in order to select the employee of the month, the performance evaluations of five warehouse personnel working in a spare parts company operating in Ankara were determined by PF-AHP and PF-MARCOS hybrid method.According to the evaluations of decision-makers, the levels of importance for the criteria are respectively as follows: "Work Quality (C1), Time Management, Attendance and Punctuality (C2), Compliance withWork Hierarchy and Work Regulations (C4), Communication Skills (C5), Teamwork (C6), Decision Making (C8), Machine and Equipment Maintainability (C3), Self Education and Development (C7)." Based on these results, the following conclusions have been drawn.

- In the evaluation of warehouse employees, work quality, time manngement, attendance and punctuality, compliance withwork hierarchy and work regulations are the top three most desirable and essential parameters. This statement emphasizes the paramount importance of these parameters when assessing the performance of warehouse employees working in spare part company. Work quality underscores the significance of the quality of work that warehouse employees deliver, implying that employees are expected to complete their tasks accurately, efficiently, and to a high standard. Time management is crucial in a warehouse setting where tasks are often time-sensitive, requiring employees to manage their time effectively to meet deadlines and prioritize tasks to avoid workflow delays. Attendance and punctuality are foundational aspects of employee reliability, involving consistent attendance and arriving on time for shifts, contributing to uninterrupted workflow and operational efficiency. Furthermore, compliance with work hierarchy and work regulations signifies the importance of employees adhering to the organizational structure and workplace rules and guidelines, ensuring a safe and compliant working environment. These parameters are prioritized in performance evaluations as they directly impact the productivity, reliability, and overall success of warehouse operations.
- In line with expectations, "Quality of Work" was identified as the most important parameter. This finding is attributed to the fact that the services of warehouse workers should primarily be performed in a quality manner. Work quality is an important performance criterion for warehouse employees working in a spare parts company because in this sector, work quality is a critical factor that influences customer satisfaction. Spare parts companies need to meet their customers' needs with accurate and high-quality products delivered on time. Work quality encompasses tasks such as accurate inventory management, proper packaging, and safe transportation of products during this process. Sending incorrect or subpar products can lead to customer dissatisfaction, negatively impact the company's reputation, and potentially harm long-term customer relationships. Additionally, work quality enhances stock efficiency by improving inventory management and ensuring product safety. It also increases operational efficiency by facilitating smooth workflow. As a result, work quality is considered a vital criterion that affects the performance of warehouse employees and plays a crucial role in enhancing customer satisfaction, maintaining the company's reputation, increasing operational efficiency, and reducing costs in the spare parts industry.
- Additionally, it has been observed that communication skills and teamwork play a significant role in warehouse employee’s performance evaluation processes. Warehouse employees should interact with each other while performing essential tasks such as the orderly storage of goods, organizing shipments, and keeping inventory up to date. Good communication skills facilitate this coordination and make business processes more efficient. Moreover, the cost of errors, such as incorrect deliveries, missing inventory,

or faulty orders, can be substantial, and communication skills can help reduce such mistakes. Team members can quickly identify and rectify potential errors. However, warehouse environments are often hazardous, and safety is of paramount importance. Effective communication is necessary to ensure the safety of colleagues. In conclusion, communication skills and teamwork are of critical importance for warehouse employees as they enhance the efficiency of business processes, reduce errors, increase safety, and facilitate problem-solving.

According to the employees' performance levels, the fourth employee's performance took the first place. The performance of the second employee ranked second. The performance of the third employee ranked third. The performance of the first employee was in the last place. According to these results, the recommendations for the managers are as follows:

- The fourth employee has consistently demonstrated an exemplary level of performance, surpassing the established criteria more effectively than their peers. Recognizing and rewarding such exceptional performance is not only essential but can also serve as a source of motivation for the entire workforce. There are several suggestions in this respect. Firstly, monetary rewards remain a potent motivator and should be an integral part of the recognition strategy. Offering financial incentives, such as bonuses or salary increases, can provide a tangible and immediate acknowledgment of the fourth employee's outstanding contributions. However, it's essential to ensure that these rewards are commensurate with the level of performance to maintain fairness and equity in the workplace. Moreover, flexible working conditions can be a valuable non-monetary incentive. Allowing the fourth employee to have more control over their work hours or providing opportunities for remote work can contribute to a better work-life balance. This flexibility not only recognizes their exceptional performance but also enhances their overall job satisfaction and well-being. In addition to these, rewards that offer social benefits can have a significant impact. Public recognition and appreciation within the organization can go a long way in motivating not only the fourth employee but also inspiring others to excel. Highlighting their achievements through internal communication channels, such as newsletters or company meetings, can create a sense of pride and encourage a culture of high performance. Furthermore, career development opportunities should not be overlooked. Providing the fourth employee with a clear path for advancement or additional responsibilities can be a powerful motivator. It not only acknowledges their current achievements but also demonstrates the organization's commitment to nurturing and promoting talent from within.
- The first employee is in the last place in the performance evaluation. Certain measures and improvements need to be taken for this employee. To begin with, placing the employee at the lowest rank in the performance evaluation signifies the need for a deliberate and proactive approach to enhance their capabilities. This involves exposing them to diverse experiences, such as job rotations, participation in problem-solving

scenarios using simulations, and active involvement in decision-making processes. These experiences serve as invaluable learning opportunities, helping the employee acquire new skills and broaden their understanding of the organization's operations. Furthermore, investing in targeted training programs is essential to address specific areas that require improvement. Emphasis should be placed on skill development in critical areas such as work quality, time management, attendance, and punctuality. Effective time management skills enable employees to prioritize tasks, meet deadlines consistently, and boost overall productivity. Additionally, cultivating a strong sense of punctuality and reliability in attendance is not only a hallmark of professionalism but also fosters a more cohesive and efficient work environment. Supporting the employee's growth and development also involves the introduction of motivating factors. These incentives can take various forms, including recognition for their efforts, opportunities for career advancement, or rewards based on performance. Tangible rewards and acknowledgment of their progress serve as powerful motivators, igniting the employee's drive and encouraging a heightened commitment to continual improvement.

- Necessary feedback should be given to fifth employee to improve performance. It is thought that the measures and improvements to be taken for the fourth employee should also be addressed for this employee.

As a result of the research, the suggestions and implications to the researchers are as follows:

- Employee performance evaluation problems can indeed benefit from various Multi-Criteria Decision-Making (MCDM) methods. These methods are designed to assist organizations in effectively assessing and managing the performance of their employees. MCDM techniques such as the Analytic Network Process (ANP) or the Simple Additive Weighting (SAW) method offer structured approaches to consider multiple criteria and make informed decisions regarding employee performance.
- Employee performance evaluation problems are not limited to a single sector or industry. In fact, they can be adapted and applied to various sectors by tailoring the evaluation criteria to suit the specific needs and objectives of each sector. Different industries may have distinct performance metrics and standards, and it's essential to customize the evaluation process accordingly. For example, criteria for evaluating the performance of healthcare professionals will differ from those for evaluating software developers.
- Enhancing expert evaluations and incorporating more refined assessment methods can be achieved through consultations and interviews with senior managers within companies. These senior managers often possess valuable insights and experience that can contribute to a more comprehensive understanding of employee performance. By conducting interviews and gathering input from these experts, organizations can improve their evaluation processes, making them more sensitive and accurate.

Additionally, comparing the findings obtained through these methods with the performance of other employees can provide valuable benchmarks and insights for continuous improvement and talent development within the organization.

The results of this study show that the PF-AHP and PF-MARCOS hybrid method can be used as an effective tool to objectively evaluate and improve employee performance. It can also be emphasized that future studies need to be done to examine and validate the expanded applications of this method in different sectors and cultural contexts. Such reviews can help businesses maintain a competitive advantage by maximizing their leadership capacity. In addition, this study contributes to the literature as it makes employee selection by using PF-AHP and PF-MARCOS methods together.

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